

EXHIBIT 5

To

**DECLARATION OF ALEXANDER E. GASSER
IN SUPPORT OF
DEFENDANTS OPTREX'S, FUJIFILM'S AND
SAMSUNG SDI'S OPENING MEMORANDUM OF LAW
IN SUPPORT OF THEIR PROPOSED CLAIM CONSTRUCTION**

S7-7 Directional Diffuser Lens Array for Backlit LCDs

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Honeywell v Apple
Date 2-6-07
Defendant
EXHIBIT 63

ABSTRACT

A directional type diffuser for backlit liquid crystal displays (LCDs) is presented. Constructed with low-cost, thin, molded plastic lens array(s) and inserted behind the LCD panel, results are: increased brightness, better uniformity, darker blacks off-axis, and better gray-scale stability with viewing angle. The approach is suitable for all transmissive displays including TN, STN, F-E, TVs, laptop PCs, avionics, and other applications.

Objectives and Background

The conventional practice for backlighting large area, liquid crystal, matrix displays (passive or active) consists of a fluorescent lamp behind a diffusing plate that projects light through the LCD.^[1] The diffusing plate is typically as lambertian as practical to prevent imaging of the lamp. That is, the diffuser deliberately scatters light uniformly across angle without preference for any direction. This typical configuration serves several practical purposes. Among those practical purposes are hiding the lamp image from the viewer, facilitating the human visual system in establishing the LCD surface as the image plane, and allowing the LCD to be equally well backlit from all viewing angles for a minimum of cost, complexity and space. See Figure 1.

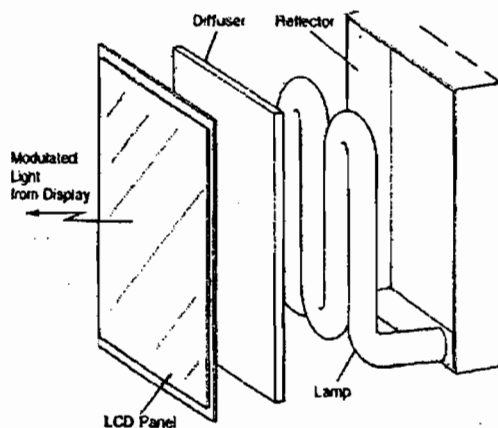


Figure 1. Exploded View of a Typical Backlit LCD

While backlighting through a lambertian diffuser provides virtually constant luminance into the rear display surface throughout all viewing angles, the transmission function of the LCD is not constant with viewing angle. This is a well known shortcoming of LCD technology. Partly due to this transmission instability with viewing angle, the practical uses for this class of display have been limited to applications with confined viewing space such as personal TVs, PC displays, video camera viewfinders, etc. Our application, flight instruments for aircraft cockpits, share common features with typical matrix LCD applications including a limited field of angular view and an undesirable, but significant, instability in the LCD transmission with viewing angle. See Figure 8.

In typical direct view applications, the limited viewing angle actually provides an opportunity to produce a more efficient backlight system. The opportunity arises from the fact that light radiated in unviewed directions is wasted and would be

better directed away from those angles into useful viewing angles.^[2] Obviously, this is easier said than done. We have developed a means to approach this goal by using a nonlambertian diffuser that has gain in the useful viewing angles. Naturally, as required by the conservation of energy, any gain provided by the diffuser in one direction must be offset by a loss in another direction. This is ideal for the LCD applications described here because it conserves light, directing it preferentially into useful directions while stealing it away from useless angles, thereby improving the efficiency of the backlighting system.

Not only can a directional diffuser improve efficiency, but with proper design choices, it can effectively compensate for the variability of transmission of the display with viewing angle. The directional diffuser, by definition, varies the exit luminance from its surface with viewing angle. By designing this angular variation in luminance output to be inversely proportional to the angular transmission characteristics of the panel, the panel's angular variability can be nullified. That is, when at some angle, the display is more transmissive than it is at the nominal viewing angle, that transmission error can be nullified if the luminous output from the directional diffuser at that same angle is proportionally less than it is at the nominal viewing angle. Conversely, at viewing angles where the panel is less transmissive than it is at the nominal viewing angle, that error can be nullified by a directional diffuser that produces proportionally more luminance at that angle than it does at the nominal angle.

Unfortunately, the angular transmission characteristics of an LCD panel depend largely on the gray level being displayed. It is, therefore, not generally possible to create an inverse transmission characteristic for an LCD panel with a passive directional diffuser. We can, however, approximate that end by targeting particular gray levels or families of gray levels that behave similarly with viewing angle and have a particular importance for the display.

One important gray level to target is the dark state transmission. We believe the dark state variability with viewing angle is closely related to the perceived visual quality of the display's viewing angle. This is especially true in avionics where most of the display surface is black and graphic symbols are displayed against this black background. Often, contrast is presumed to be the important figure of merit with regard to off-axis display performance. We believe, however, that high contrast in off-axis viewing angles is important to a large extent because it is typically used to reduce the dark state, off-axis luminance. That is, a key perceptual factor in accessing display quality across viewing angle is the darkness of the background. That this aspect of display quality is independent of contrast is made clear with the directional diffuser which is incapable of affecting contrast at any viewing angle, but exhibits markedly improved off-axis display quality, nonetheless, in proportions normally attributed to high contrast.

In many applications, including ours, the angular variability of lower gray level transmissions behave similarly to the dark-state transmission. Thus, tailoring the directional diffuser to reduce dark state variability has the added benefit of reducing the variability of lower gray levels as well. Maintaining the luminance stability of these lower gray levels with viewing angle is important to image quality because it is these low gray levels that are recruited to make colors such as brown, gold, and gray, for example. These "colors" are dim versions of orange, yellow and white respectively and depend just as heavily on their relative luminance to the surround

for their perception as they do on their color coordinates. Therefore, to effectively render these colors on the display over the entire angular field of view, it is important that the luminance of the low gray levels be stable with viewing angle.

Results

To construct our original directional diffuser prototype we used an off-the-shelf, 142 lenses per inch (5.6 lenses per mm), molded plastic, cylindrical lens array placed between the LCD panel and a lambertian diffuser. Figure 2 shows our modified diffusing system in cross section. An examination of first principles led us to question how this construction could produce the gains it did since refraction of the light through the lens array from a lambertian source should not produce gain. The subsequent investigation showed that there is a concert of several optical effects combining to produce gain, including diffuse reflections, lens refraction, and total internal reflections.^[3] Figure 3 shows the luminance versus angle response from the single cylindrical lens directional diffuser case compared to the angular response from the lambertian source diffuser.

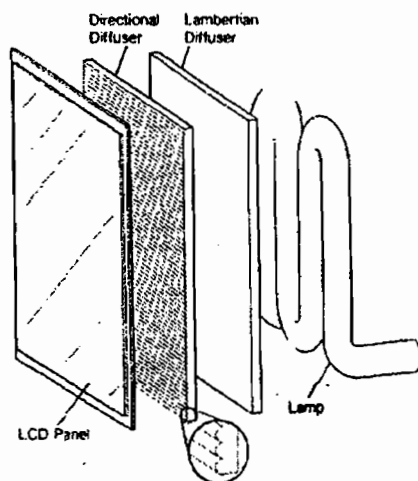


Figure 2. LCD with Directional Diffuser

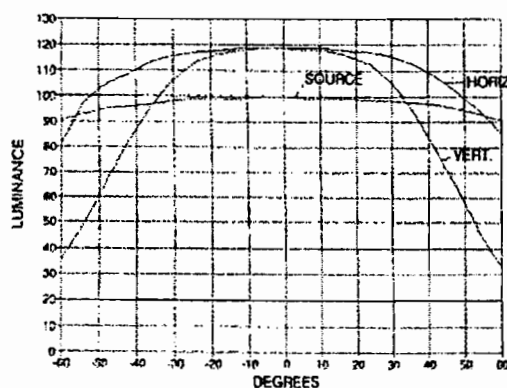


Figure 3. Single Cylindrical Lens Array Angular Emissions

Theory of Operation

As illustrated in Figure 4, light rays from the lambertian diffuser source impinge on the lens array from all angles. Rays with propagation vectors that are substantially perpendicular to the

tangent of the lens curvature pass through the lens array suffering Fresnel reflections at the entrance and exit surfaces of the lens array as well as some refraction. Note that these rays are not necessarily normal to the plane of the array but rather essentially normal to the curvature of the lens which spans 180 degrees. However, much of the intensity of rays substantially off the normal to the array will be reflected back toward the lambertian diffuser source through Fresnel reflections at the entrance surface of the array and at the lens curvature surface. These Fresnel reflections are not, in themselves, losses since the reflected light is directed back toward the lambertian diffuser. There, it is diffusely reflected again, and together with currently generated light from the lamp source, impinges on the lens a second time. However, reflections at the lambertian diffuser source are, in general, lossy as a result of some absorption in the reflections and absorption along the added optical path. We have found that these losses can be minimized by design choices, especially material selections, at great benefit to the efficiency of the lighting system.

Rays entering at oblique angles relative to the curvature of the lens, that are greater than the critical angle, undergo total internal reflection. These rays are reflected several times around the lens periphery and exit the rear of the lens array aimed back at the lambertian diffuser. As described before, these reflected rays then undergo a diffuse reflection from the lambertian diffuser source, are combined with light generated by the lamp source and are presented a second time to the rear of the lens array with another chance to pass through the LCD. Since light entering at these oblique angles is selectively rejected and realigned until accepted by the lens array, the lambertian diffuser and lens array combination preferentially transmits light in directions substantially normal to the plane of the array in the axis of the lenslets with only a modest effect on the opposing axis. See Figure 3 where vertical refers to the lenslet axis.

Alternate Configurations

This theory of operation of the prototype directional diffuser configuration serves to illustrate the basic principles involved, but does not necessarily imply the optimal arrangement or even the preferred construction of an optical element used as a directional diffuser. For example, another useful configuration results from flipping the lens array over such that the curved lens surface faces the diffuser. In this case, light exiting the diffuser impinges on the convex curvature of the lens array first. This results in preferentially directing light away from the normal to the plane of the lens array and into oblique angles. In other words, this configuration throws light into off-axis angles at the expense of on-axis luminance and can aid in cases where display brightness suffers off-axis. This configuration has an on-axis gain slightly less than one.

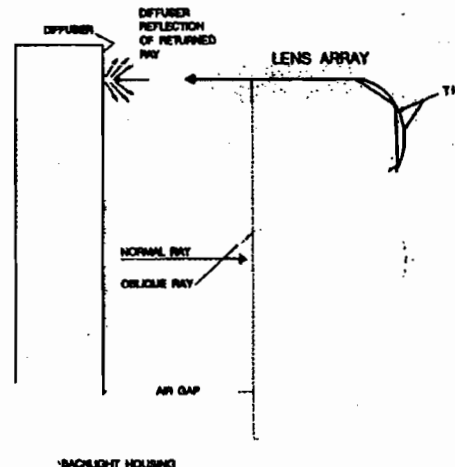


Figure 4. Sample Ray Paths Through Directional Diffuser

Combining multiple lens arrays, stacked one in front of the other relative to the light path, either with the lens' major axis aligned or rotated with respect to each other also has useful effects. Figure 5 illustrates a dual lens array configuration. As you can intuitively imagine, the pitch of the lens array is independent of the transmission versus viewing angle gain profile which depends only on the lens shape. This allowed us to combine the effects of two lens arrays with their major axis aligned without moire pattern effects by using different pitches on each array. This particular arrangement provides sharper roll off of the luminance with vertical viewing angles without much change to the on-axis gain. See Figure 6.

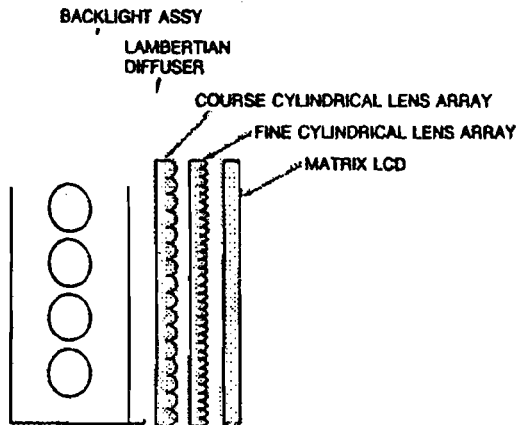


Figure 5. Dual Lens Array Configuration

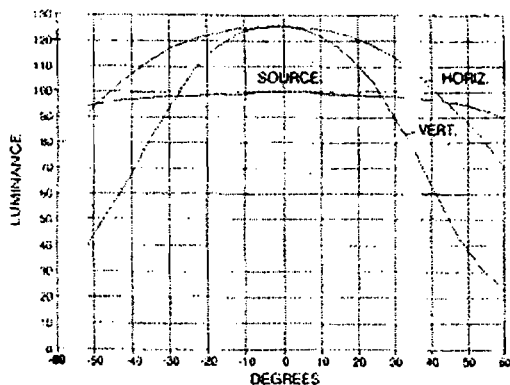


Figure 6. Dual Lens Arrays Optical Characteristic

We have been especially interested in the advantages of such tandem, rotated (90 degrees), lens arrays combined with a diffusing reflector box rather than a diffuser plate as the diffuse source. The advantages are fewer losses and better uniformity due to the larger reflector enclosure serving as an integrating cavity. While the gain profile of the lens array is independent of pitch, the diffusing power of the lenses in this configuration is very much dependent on the lens pitch.

Computer Analysis

Most commercially available optical ray trace programs are designed for imaging optics with lenses placed along an optical axis. These programs are not well suited to analyzing the directional diffuser primarily because of the lateral extension of the

diffusing source. Much of our understanding, analysis, and synthesis results of the directional diffuser came about through a customized, ray trace computer program developed for us by Fresnel Technology Inc.^[3] Ray tracing of multiple rays with a computer has verified the gains and angular distribution of emitted light from directional diffuser configurations.

This ray trace program was used to examine a number of candidate lens arrays with varying lens shapes. It was found that a triangular array with a 90 degree apex angle provided the most gain on-axis. While the angular distribution was too narrow for our application (see Figure 7), it may be well suited for other applications. The next higher gain was found to be obtained with the cylindrical lens. Asymmetrically shaped or truncated lenses yielded symmetrical angular distributions about the normal axis, but had reduced gain over non-truncated shapes. We also found that while an air gap (or other form of a refractive index discontinuity) must be present between the lambertian diffuser and lens array, the surfaces may contact randomly with no noticeable effect.

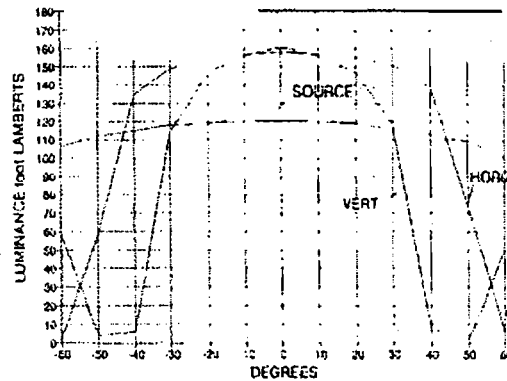


Figure 7. Triangular Lens Array Optical Characteristic

Moire Pattern Treatment

From the beginning we were certain that moire patterns would be a major obstacle to a successful realization of a practical directional diffuser married with an LCD panel. However, we were pleased to find that moire pattern, caused by the beating between the lens pitch and the display dot pitch was much easier to deal with than we first imagined. By using a lens pitch that was higher than, and between integer multiples of, the display pitch we were able to counteract most of the moire.^[4] A slight rotation of the lens array's major axis relative to the cardinal axes of the display panel served to frustrate the pattern and thereby eliminate any remaining moire for all practical purposes. Naturally, alphanumeric displays and displays with small, disassociated symbols are least susceptible to moire effects; but we were able to eliminate noticeable moire from all symbols including full-field presentations of solids and patterns.

Combined LCD and Directional Diffuser Results

Figure 8 shows the gray level luminance versus vertical viewing angle for our normally black LCD with a conventional, lambertian diffuser. Figure 9 shows this same panel performance when backlit with the dual-aligned lens arrays profiled in Figure 5. Notice how stable (flat) low level grays are near the nominal viewing angle of 15 degrees up. Also, notice that the black level (lowest gray) remains much darker across viewing angle than when backlit with a conventional diffuser.

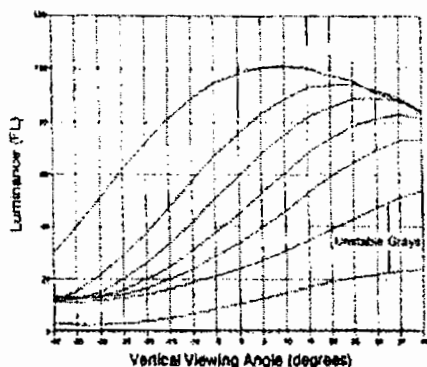


Figure 8. Gray Scale Luminance with Viewing Angle and Conventional Diffuser

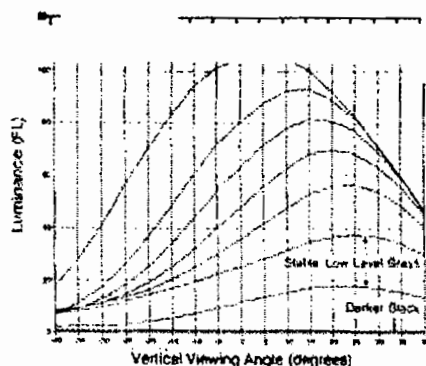


Figure 9. Gray Scale LCD Luminance with Dual Lens Directional Diffuser

Impact

We believe the molded lens array, directional diffuser we have developed and presented here with its approximate 15 percent efficiency improvement to the on-axis output from the backlight

system can benefit most LCD applications. The technique is applicable to a wide body of transmissive display technologies including TN, STN, and ferro-electric LCDs. Of particular importance to many applications is that the directional diffuser increases on-axis luminance of the backlight system that can be used in any number of ways including lower lamp power, longer lamp life and/or a brighter display. In portable applications, these benefits can translate directly into longer battery life and/or smaller size and/or lower weight. We believe that for most consumer applications, the efficiency benefit of the directional diffuser alone can justify the relatively low cost of this simple optical element. The benefits of improving display stability with viewing angle and potentially improved display uniformity across the panel, for the most part, come for free.

Acknowledgements

The authors would like to acknowledge and thank Karen Jacomowicz for her many contributions to this effort early on including a key solution to moire pattern problems. Also, Dr. Richard Claytor and his staff at Fresnel Technologies, Inc., Fort Worth, Texas, USA (especially Dr. Luigi Fornari) for their many contributions in the form of analysis and samples and enthusiasm for identifying the science behind the effect, a characteristic that took them well beyond the effort we contracted for.

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